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IRIG

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TELEMETRY STANDARDS

TELEMETRY GROUP
INTER-RANGE INSTRUMENTATION GROUP
RANGE COMMANDERS COUNCIL

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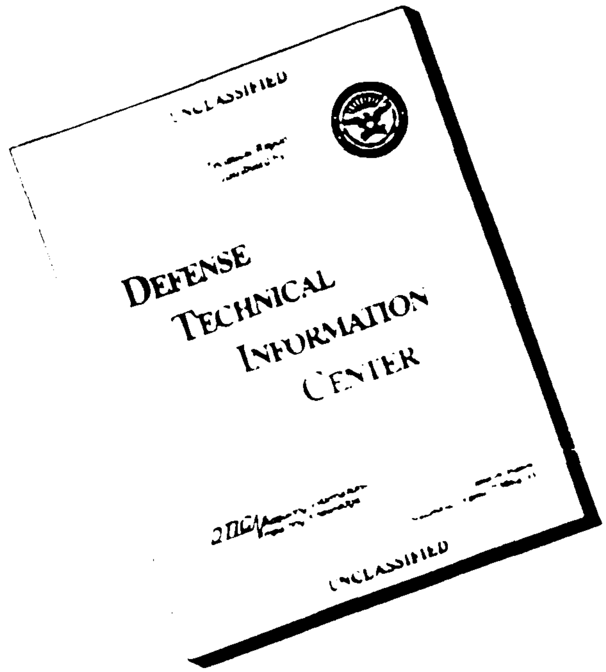

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WSMR-KMR-PMR-AFWR-NWC-AFETR-SAMTEC-ADTC-AFFTC-AFSCF

REPLY TO ATTN OF: STEWS-SA-R

SUBJECT: IRIG Standard 106-73 (Revised November 1975)

TO: Holders of IRIG Standard 106-73

1. The attached "revised" pages to the 106-73 have been approved by both the Telemetry Group and the RCC Executive Committee.

2. The following is provided to facilitate the removal of outdated pages and the insertion of revised pages:

Remove	Insert (using the attached)
Cover	Cover
Title Page	Title Page
Contents (iii/vi)	Contents (iii/v)
Appendices (vii)	List of Appendices (vii)
List of Tables (viii)	List of Tables (viii)
List of Figures (ix)	List of Figures (ix)
Footnotes (x)	Footnotes (x)
Pages: 1-2, 5 thru 18, 23 thru 26, 43 thru 46, A-1/A-2, A-5 thru A-8 B-1/B-2, B-5 thru B-11, C-1, E-1, G-1 thru G-3	Pages: 1-2, 5-6, 7-8, 9-10, 11 thru 14 (one page), 15-16, 17-18, 18A-18B, 23 thru 26 (one page), 43-44, A-1/A-2, A-5/A-6 A-7/A-8, B-1/B-2, B-5, C-1/C-2 C-3, E-1, G-1 thru G-3

Robert J. O'Leary

ROBERT J. O'LEARY
Executive Secretary
Range Commanders Council

DOCUMENT 106-73

TELEMETRY STANDARDS
Revised November 1975

Containing International (SI) Units
and Conventional Units

TELEMETRY GROUP
INTER-RANGE INSTRUMENTATION GROUP
RANGE COMMANDERS COUNCIL

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FOOTNOTES

1. Certain short-term waivers that have been granted to DOD components will permit some flexibility in effecting full conversion to UHF telemetry. Users with waivers which permit continued operations in the 225-260 MHz band will adhere to telemetry standards contained in Chapter 1 of this publication.

2. For radiated measurements this value will be the equivalent of -25 dbm as referenced to the unmodulated carrier power.

3. Flight testing telemetry is defined as telemetry which is used in support of research, development, test and evaluation, and which is not integral to the operational function of the system.

4. W-T-001553, Tape, Recording, Instrumentation, Amendment 2.

5. Reels and Hubs for Magnetic Recording Tape. General Specifications for (W-R-175B) Reels, Standard, Fiberglass and Metallic. 3-Inch Center-Hole (W-R-175/3b) Reels, Precision, Aluminum and Magnesium; 3-Inch Center-Hole (W-R-175/4b) Reels, Precision, Glass Flange With Aluminum Hub; 3-Inch Center-Hole (W-R-175/6-T).

6. K. M. Uglow, "Noise and Bandwidth in FM/FM Radio Telemetry," IRE Transactions on Telemetry and Remote Control, May 1957, pp. 19-22.

CHAPTER 1

INTRODUCTION

Section I. GENERAL

1-1. General.

The Telemetry Group of the Range Commanders Council (RCC) has prepared this document of standards to foster the compatibility of telemetry transmitting, receiving, and signal processing equipment at all the Test and Evaluation (T&E) ranges under the cognizance of the RCC. The Range Commanders highly recommend that telemetry equipment operated at the T&E ranges, and telemetry equipment utilized by the range user in programs that require test range support, conform to these standards.

1-2. Scope.

These standards do not necessarily define the existing capability of any test range but constitute a guide for the orderly implementation and application of telemetry systems for both the ranges and range users. The scope of capabilities attainable with the utilization of these standards requires careful consideration of tradeoffs. Guidance concerning these tradeoffs is provided in the text.

1-3. Purpose.

These current standards provide development and coordination agencies with the necessary criteria on which to base equipment design and modification. The ultimate purpose is to ensure efficient spectrum and interference-free operation of the radio link for telemetry systems at the RCC member ranges.

a. A companion document 118-73 (Revised July 1975) - Test Methods for Telemetry Systems and Subsystems - has been published in conjunction with 106-73 (Revised November 1975).

b. It is the policy of the Telemetry Group to update the Telemetry Standards and Test Procedures approximately every two years. IRIG 106-73 (Revised November 1975) supersedes IRIG 106-73 and all previous standards listed in Section 1 of 106-73. IRIG 118-73 (Revised July 1975) supersedes IRIG 118-73.

c. Metric conversions are included in this edition and are shown following the conventional units.

1-4. Reference Documents.

Reference documents are identified at the point of reference.

1-5. Definitions

Commonly used terms are as defined in any standard reference glossary or dictionary unless otherwise indicated. Definitions of terms with special application are included where the term first appears.

1-6. General Statements or Requirements

The general statements or requirements are contained in each section of this document.

Section II. DETAILED REQUIREMENTS

1-7. Frequency Parameters and Criteria of Telemetry Transmitter and Receiver Systems

Throughout this Section, and applicable to all systems in this document, when specifying radio-frequency bandwidth, the transmitter and receiver shall be considered a system. Systems not adhering to these standards will be subjected to a critical review.

1-8. Frequency Band 225 to 260 MHz.

This frequency band was reallocated to fixed and mobile communications services effective 1 January 1970. The Military Communications Electronics Board will consider temporary VHF telemetry waivers, on an individual basis, subject to the following limitations:

a. Military test vehicles used must be part of the current inventory and originally configured with 225-260 MHz telemetry systems.

b. Available facts must clearly support the contention that the use of telemetry equipment in the 1435-1535 MHz or 2200-2290 MHz bands would be prohibitively expensive or impractical, or that significant test program slippage would occur if conversion retrofit is required.

c. Ranges and test sites selected to support the proposed operations can provide VHF telemetry support without installation of additional equipment.

d. Operations will be limited to the frequency bands listed in Table 1 below.

TABLE 1 Radio Frequency Telemetry Assignments

226.7 MHz	237.0 MHz	246.3 MHz	*258.5 MHz
230.4 MHz	239.4 MHz	248.6 MHz	259.7 MHz
231.9 MHz	240.2 MHz	250.7 MHz	
232.9 MHz	244.3 MHz	253.8 MHz	
235.0 MHz	245.3 MHz	256.2 MHz	

***Not available for telemetry waiver beyond 1 January 1975, due to conflict with planned satellite communications.**

e. The use of VHF telemetry on the foregoing frequencies beyond 1 January 1975 will not be a bar to the satisfaction of communications needs for which the 225-400 MHz band is primarily allocated.

f. Frequency allocation applications proposing development or procurement of new telemetry equipment designed to operate in the 225-260 MHz band will not be approved.[1]

b. 1485-1535 MHz. Use of these channels is primarily for flight testing of unamnned aircraft and missiles or major components thereof, and secondarily for flight testing of manned aircraft.

2-5. Allocation of 2200–2300 MHz Band

Telemetering other than flight testing of manned aircraft is described below. Refer to Appendix A for guidance on specific radio frequencies available for satisfying various channel bandwidth requirements.

a. 2200-2290 MHz. Use of these channels is on a co-equal shared basis with government fixed and mobile communications. Use of these channels includes telemetry associated with launch vehicles, missiles, upper atmosphere research rockets, and space vehicles, regardless of their trajectories.

b. 2290-2300 MHz. Channels in this band are for space research telemetry on a shared basis with fixed and mobile services.

2-6. Transmitter Systems

a. Frequency Tolerance. The transmitter radio-frequency carrier, (modulated or unmodulated) shall be within 0.003 per cent of the assigned radio frequency under all operating conditions and environments.

NOTE

Between 1 and 5 seconds after initial turn-on, the transmitter radio frequency shall remain within 0.005 per cent of the assigned radio frequency. After 5 seconds, the specified frequency tolerance is applicable for any and all operations in which the conducted power level is greater than -25 dbm for a duration of one or more seconds. If radiated measurements become necessary for the determination of frequency, the ±0.003 per cent frequency tolerance shall apply when a field intensity of greater than 500 microvolts per meter is experienced at any radial distance of 100 feet (30.48 meters) from the transmitter system.

b. Power. The power shall be as directed by the intended use, and never more than absolutely necessary for reliable telemetry reception.

c. Spurious Emission and Interference Requirements Using Test Methods and Equipment in Accordance With Applicable Military Standards or Specification. (Antenna Conducted or Antenna Radiated 0.150 to 10,000 MHz).

(1) Emissions from the transmitter-antenna system are of primary importance. Spurious and harmonic outputs, antenna-conducted (i.e., measured in the antenna transmission line) or antenna-radiated (i.e., measured in free space), shall be limited to the values derived from the formula:

db (down unmodulated carrier) = $55 + 10 \log_{10} P_t$
where P_t is the measured output power in watts.

NOTE

This limits all conducted spurious and harmonic emissions to a maximum power level of -25 dbm.

Radiated tests will only be used when the transmission line is inaccessible for conducted measurements.

Conducted or radiated spurious emissions will be checked under unmodulated conditions.

(2) Interference (Conducted and Radiated). All interference voltages (0.150 to 25 MHz) conducted by the power leads and interference fields (0.150 to 10,000 MHz) radiated directly from equipment, units or cables, shall be within the limits specified by the applicable Military Standard or Specification.

d. Flexibility of Operation. The transmitter shall be capable of operating throughout the entire frequency band from 1435 to 1535 MHz and/or 2200-2300 MHz, without design modifications.

e. Bandwidth (Transmitter Modulated). Refer to paragraph 5 of Appendix A, for channel bandwidth definitions and spacing allocations and to paragraph 7 of Appendix A for standards for the level of undesired emissions outside the authorized bandwidth for telemetering stations excluding those for space radio communications in the 1435-1535 and 2200-2290 MHz bands.

2-7. Receiver Systems.

a. Spurious Emissions (0.150 to 10,000 MHz). Radio-frequency energy, both radiated from the unit and antenna-conducted, shall be within the limits specified in the applicable Military Standard or Specification.

b. Interference Protection. Radio-frequency interference protection will be provided only for systems using receivers which meet the following criteria:

(1) Frequency Tolerance. The combined errors of all local oscillators of the receivers shall not exceed 0.001 per cent of the assigned frequency under operating conditions during mission support.

(2) Spurious Responses (0.150 to 10,000 MHz). Shall be more than 60 db below the fundamental frequency response.

(3) Flexibility of Operation. The system shall be operable over the entire 1435 to 1535 MHz band and/or 2200 to 2300 MHz band, without design modification, and will have variable bandwidth selection.

CHAPTER 3

FREQUENCY DIVISION MULTIPLEXING TELEMETRY STANDARDS

Section I. INTRODUCTION

3-1. General

In frequency division multiplexing, each data channel makes use of a separate subcarrier which occupies a defined position and bandwidth in the modulation baseband of the RF carrier. Two types of FM subcarrier formats may be utilized; the data bandwidth of one type is proportional to the center frequency of the subcarrier, while the data bandwidth of the other type is constant, regardless of subcarrier frequency.

3-2. Scope

The following sections set forth the standards for utilization of FM frequency division multiplexing.

Section II. FM SUBCARRIERS

3-3. Characteristics

In these systems, one or more subcarrier signals, each at a different frequency, are employed to frequency modulate (FM) or phase modulate (PM) a transmitter in accordance with the radio-frequency conditions specified in Chapter 2.

a. Each of the subcarriers convey measurement data in the form of frequency modulation. The number of data channels may be increased by modulating one or more of the subcarriers with a time division multiplex format such as Pulse Code Modulation (PCM), Pulse Amplitude Modulation (PAM).

b. The selection and grouping of subcarrier channels depend upon the data bandwidth requirements of the application at hand, and upon the necessity to ensure adequate guard bands between channels. Combinations of both proportional-bandwidth channels and constant-bandwidth channels may be used.

3-4. FM Subcarrier Channel Characteristics

Table 2 lists the standard proportional-bandwidth FM subcarrier channels. The channels identified with letters permit ± 15 per cent subcarrier deviation rather than ± 7.5 per cent

TABLE 2. PROPORTIONAL–BANDWIDTH FM SUBCARRIER CHANNELS

±7.5% CHANNELS

Channel	Center Frequencies (Hz)	Lower Deviation Limit* (Hz)	Upper Deviation Limit* (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response** (Hz)*	Minimum Rise Time** (ms)
1	400	370	430	6	58	30	11.7
2	560	518	602	8	42	42	8.33
3	730	675	785	11	32	55	6.40
4	960	886	1,032	14	42	72	4.86
5	1,300	1,202	1,398	20	18	98	3.60
6	1,700	1,572	1,828	25	14	128	2.74
7	2,300	2,127	2,473	35	10	173	2.03
8	3,000	2,775	3,225	[illegible]	7.8	225	1.56
9	3,900	3,607	4,193	59	6.0	293	1.20
10	5,400	4,995	5,805	81	4.3	405	.864
11	7,350	6,799	7,901	110	3.2	551	.635
12	10,500	9,712	11,288	160	2.2	788	.444
13	14,500	13,412	15,588	220	1.6	1,088	.322
See Sec. 3-4							
14	22,000	20,350	23,650	330	1.1	1,650	.212
15	30,000	27,750	32,250	450	.78	2,250	.156
16	40,000	37,000	43,000	600	.58	3,000	.117
17	52,500	48,562	56,438	790	.44	3,938	.089
18	70,000	64,750	75,250	1050	.33	5,250	.067
19	93,000	86,025	99,975	1395	.25	6,975	.050
See Sec. 3-5							
20	124,000	114,700	133,300	1860	.19	9,300	.038
21	165,000	152,624	177,375	2475	.14	12,375	.029

±15% CHANNELS***

Channel	Center Frequencies (Hz)	Lower Deviation Limit* (Hz)	Upper Deviation Limit* (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response** (Hz)*	Minimum Rise Time** (ms)
A	22,000	18,700	25,300	660	.53	3,330	.106
B	30,000	25,500	34,500	900	.39	4,500	.078
C	40,000	34,000	46,000	1200	.29	6,000	.058
D	52,500	44,625	60,375	1575	.22	7,875	.044
E	70,000	59,500	80,500	2100	.17	10,500	.033
F	93,000	79,050	106,950	2790	.13	13,950	.025
G	124,000	105,400	142,600	3720	.09	18,600	.018
H	165,000	140,250	189,750	4950	.07	24,750	.014

* Rounded off to nearest Hz.

** The indicated maximum data frequency response and minimum rise time is based upon the the maximum theoretical response that can be obtained in a bandwidth between the upper and lower frequency limits specified for the channels. (See Chapter 3, Sec. II and referenced discussion in Appendix B for determining possible accuracy versus response tradeoffs.)

*** Channels A through H may be used by omitting adjacent lettered and numbered channels. Channels 13 and A may be used together with some increase in adjacent channel interference.

deviation, but use the same center frequencies as the eight highest numbered channels. The channels shall be used within the limits of maximum subcarrier deviation (See Appendix B for expected performance tradeoffs at selected combinations of deviation and modulating frequency). There is a ratio of approximately 1.33 to 1 between the center frequencies of adjacent ± 7.5 per cent proportional bandwidth channels, except between 14.5 KHz and 22 KHz where a larger gap is left to provide a 60 Hz amplitude modulated 17 KHz carrier for capstan speed control of magnetic-tape recorders (See Chapter 7, para. 7-3h.(2)(a)). The use of an additional FM subcarrier between 14.5 and 22 KHz is not permissible.

NOTE

Table 3 lists the standard FM constant-bandwidth FM subcarrier channels. The letters A, B and C identify the channels for use with maximum subcarrier deviations of ± 2 KHz, ± 4 KHz and ± 8 KHz, along with maximum frequency responses of 2, 4, and 8 KHz, respectively. The channels shall be used within the limits of maximum subcarrier deviation. (See Appendix B for expected performance tradeoffs at selected combinations of deviation and modulating frequency.)

3-5. Tape Speed Control and Flutter Compensation

Tape Speed control and flutter compensation for FM/FM formats may be accomplished as indicated in 7-3 h. Use of the standard reference frequency shall be in accordance with the criteria of Table 4, when the reference signal is mixed with data.

Section III. AM SUBCARRIERS

NOTE

These standards have been deleted due to lack of use. Ranges which have an established capability are encouraged to maintain it as long as current needs exist; however, application of other standards is recommended for new programs. It is recommended that the ranges not buy new equipment related to these deleted standards.

TABLE 3. CONSTANT–BANDWIDTH FM SUBCARRIER CHANNELS

A CHANNELS		B CHANNELS		C CHANNELS	
Deviation limits = ±2 KHz Nominal frequency response = 0.4 KHz Maximum frequency response = 2 KHz*		Deviation limits = ±4 KHz Nominal frequency response = 0.8 KHz Maximum frequency response = 4 KHz*		Deviation limits = ±8 KHz Nominal frequency response = 1.6 KHz Maximum frequency response = 8 KHz	
Channel	Center Frequency (KHz)	Channel	Center Frequency (KHz)	Channel	Center Frequency (KHz)
1A	16				
2A	24				
3A	32	3B	32	3C	32
4A	40				
5A	48	5B	48		
6A	56				
7A	64	7B	64	7C	64
8A	72				
9A	80	9B	80		
10A	88				
11A	96	11B	96	11C	96
12A	104				
13A	112	13B	112		
14A	120				
15A	128	15B	128	15C	128
16A	136				
17A	144	17B	144		
18A	152				
19A	160	19B	160	19C	160
20A	168				
21A	176	21B	176		

*The indicated maximum frequency is based upon the maximum theoretical response that can be obtained in a bandwidth between deviation limits specified for the channel. (See discussion in Appendix B for determining practical accuracy versus response tradeoffs.)

TABLE 4. REFERENCE SIGNAL USAGE
Reference and Data Signals on Same Track

Reference Frequency kHz		Subcarrier Usage
*240	± 0.01%	For use with all center frequencies
200	± 0.01%	For use with all center frequencies except Channel H
100	± 0.01%	Use with center frequencies up to and including 80 KHz
50	± 0.01%	Use with center frequencies up to and including 40 KHz except Channel C
25	± 0.01%	Use with center frequencies up to and including 16 KHz
12.5	± 0.01%	Use with center frequencies up to and including 7.35 KHz
6.25	± 0.01%	Use with center frequencies up to and including 3.9 KHz
3.125	± 0.01%	Use with center frequencies up to and including .960 KHz

* For flutter compensation only, not for tape speed control.

If the reference signal is recorded on a separate track, any of the listed reference frequencies may be used, provided the requirements for compensation rate of change are satisfied.

Table 4 shows that the 240 KHz reference frequency is the only permissible frequency when Channel H is included in the multiplex and the reference signal is mixed with the data. In addition, the 240 KHz reference signal may be used as a translation frequency in a constant-bandwidth format, provided the reference signal is suitably divided down, to 80 KHz for example.

In addition to the reference frequencies listed in Table 4, which are of the constant-amplitude type, an amplitude modulated signal centered at 17 KHz ± 0.5% may be used for servo speed correction. See Chapter 7, Paragraph 7-3 (h)(2). Channel 1A must be deleted if the 17 KHz signal is multiplexed with subcarrier signals.

CHAPTER 4

PULSE CODE MODULATION (PCM) STANDARDS

Section I. INTRODUCTION

4-1. General

Pulse Code Modulation (PCM) data, the characteristics of which are specified herein, shall be transmitted as serial binary-coded time-division multiplexed samples using the sequence of pulses within each sample to represent a discrete magnitude of the data. The standard defines recommended pulse train structure and design characteristics for the implementation of pulse code modulation telemetry systems.

Section II. DESCRIPTION AND DATA

4-2. Word and Frame Structure

The PCM frame shall contain a known number of bit intervals, all of equal duration, unless special identification bits within the bit stream indicate a change. The duration of the bit interval and the number of bit intervals per frame shall remain fixed from frame to frame. All words in the frame shall contain the same number of bit intervals. Figure 1 is a graphical representation of the following structure.

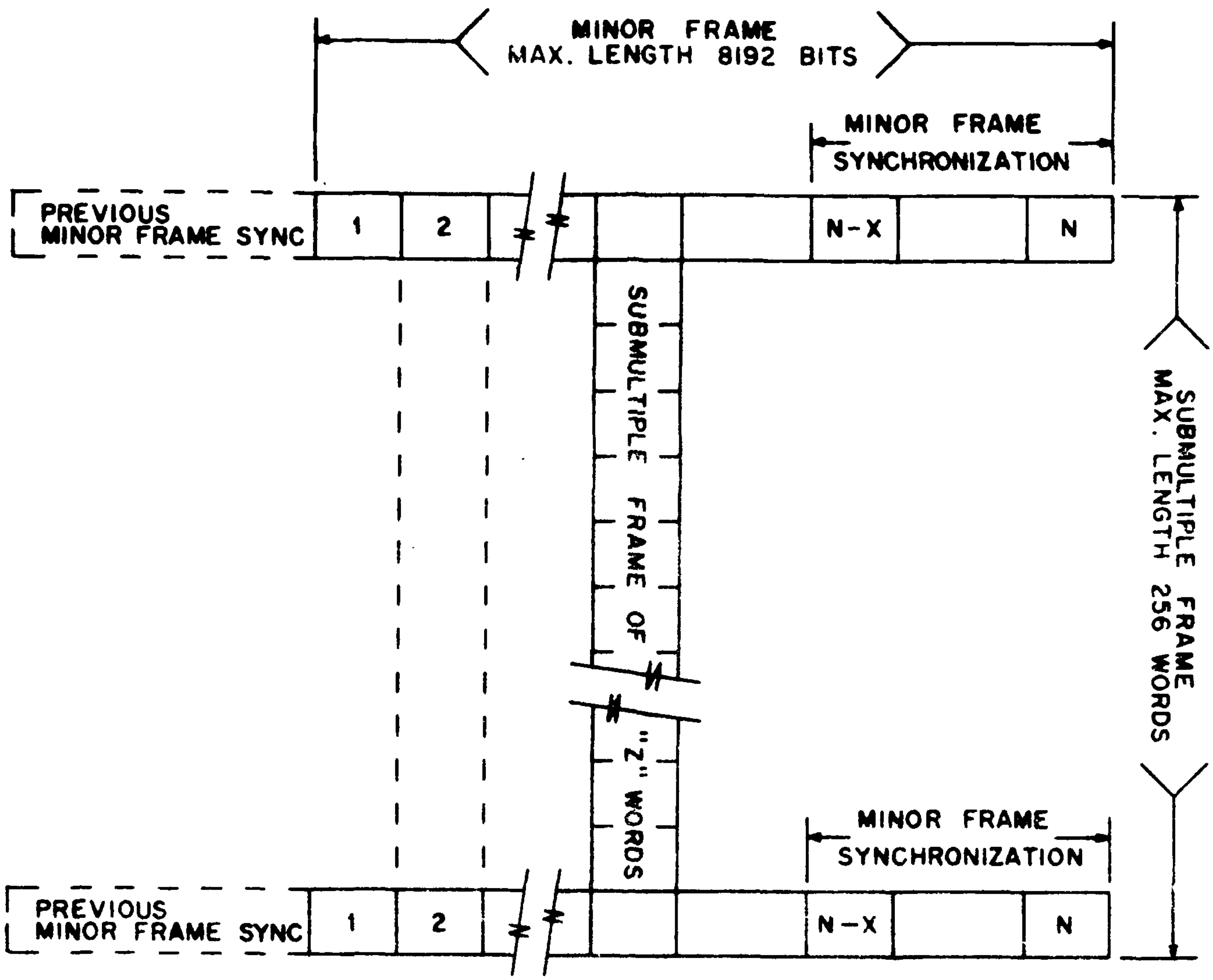
NOTE

In PCM formats, the minor frame is defined as that period between synchronization words which includes one complete cycle of the commutator having the highest rate. The major frame which includes one or more minor frames is defined as that period in which all data is sampled once.

a. Major Frame Length. The length of the major frame shall have no restriction.

b. Minor Frame Length. The length of a minor frame shall not exceed 8192 bit intervals, including the intervals devoted to synchronization.

c. Minor Frame Synchronization. The minor frame synchronization information shall consist of a digital word not longer than 33 bits in consecutive bit intervals. Recommendations concerning synchronization patterns are shown in Appendix C.



- SUBMULTIPLE FRAME SYNCHRONIZATION LOCATION IS DEPENDENT ON METHOD CHOSEN IN PARAGRAPH 4-4 a.

- BY DEFINITION A MAJOR FRAME CONTAINS (N)(Z) WORDS.

"Z" = THE NUMBER OF WORDS IN LONGEST SUBMULTIPLE FRAME.

"N" = THE NUMBER OF WORDS IN MINOR FRAME.

"X" = THE NUMBER OF WORDS IN MINOR FRAME SYNC.

Figure 1. PCM Major Frame Structure

d. Word Length. Individual words shall not be less than 4 bits nor more than 64 bits in length. Within these limits, words of different length may be multiplexed in a single minor frame. However, the length of a word in any position within a minor frame shall be constant, except during changes caused by special identification bits appearing in the bit stream.

e. Special Words. The assignment of word positions to convey special information on a programmed basis in designated minor frames is permissible. The number of bits in the substituted words, including identification and padding bits, shall equal exactly the number of bits in the replaced words.

f. Word Numbering. To provide consistent notation, the first word after synchronization shall be numbered "one." Each subsequent word shall be numbered sequentially for minor frames and submultiple frames.

g. Binary Bit Representation. The following conventions for representing binary "one" and "zero" are permissible:

NRZ-L	DM-M	BIØ-L
NRZ-M	DM-S	BIØ-M
NRZ-S		BIØ-S

Graphic and verbal descriptions of these conventions are shown in Figure 1A. Only one convention shall be used in a single PCM pulse train.

4-3. Bit Rate

The maximum bit rate is limited only by the requirements in Table 1 and Chapter 2. Receiver intermediate frequency (IF) bandwidths should be selected from Table 6. The minimum rate shall be 1 bps.

a. Bit Rate Accuracy and Stability. During any period of desired data, the bit rate shall not differ from the specified nominal bit rate by more than 1 percent of the nominal rate.

b. Bit Jitter. Any transition in the PCM waveform occurring within interval P shall occur within 0.1 bit period of the time at which such transition is expected to occur based upon the measured average bit period as determined during the immediately preceding interval P. The interval P for the purpose of this requirement, shall be equal to the measured time for five successive minor frames.

$$\text{Average Bit Period} = \frac{P}{\text{Specified Bits Per Minor Frame X 5}}$$

CODE DESIGNATIONS	LOGIC WAVEFORM LEVELS	CODE DEFINITIONS
NRZ — L	"1" / "0"	**NON-RETURN-TO-ZERO-LEVEL** "One" is represented by one level. "Zero" is represented by the other level.
NRZ — M	"1" / "0"	**NON-RETURN-TO-ZERO-MARK** "One" is represented by a change in level. "Zero" is represented by no change in level.
NRZ — S	"1" / "0"	**NON-RETURN-TO-ZERO-SPACE** "One" is represented by no change in level. "Zero" is represented by a change in level.
BIØ — L	"1" / "0"	**BI-PHASE LEVEL (SPLIT PHASE)** Level change occurs at center of every bit period. "One" is represented by a "one" level with the transition to the "zero" level. "Zero" is represented by a "zero" level with the transition to the "one" level.
BIØ — M	"1" / "0"	**BI-PHASE-MARK** Level change occurs at the beginning of every bit period. "One" is represented by a midbit level change. "Zero" is represented by no midbit level change.
BIØ — S	"1" / "0"	**BI-PHASE-SPACE** Level change occurs at the beginning of every bit period. "One" is represented by no midbit level change. "Zero" is represented by a midbit level change.
DM — M	"1" / "0"	**DELAY MODULATION-MARK (MILLER CODE)** "One" is represented by a level change midbit time. "Zero" followed by a "zero" is represented by a level change at the end of the first "Zero" bit. No level change occurs when a "zero" is preceded by a "one".
DM — S	"1" / "0"	**DELAY MODULATION-SPACE (MILLER CODE)** "Zero" is represented by a level change at midbit time. "One" followed by a "one" is represented by a transition at the end of the first "one" bit. No level change occurs when a "one" is preceded by a "zero".

CODE WAVEFORMS

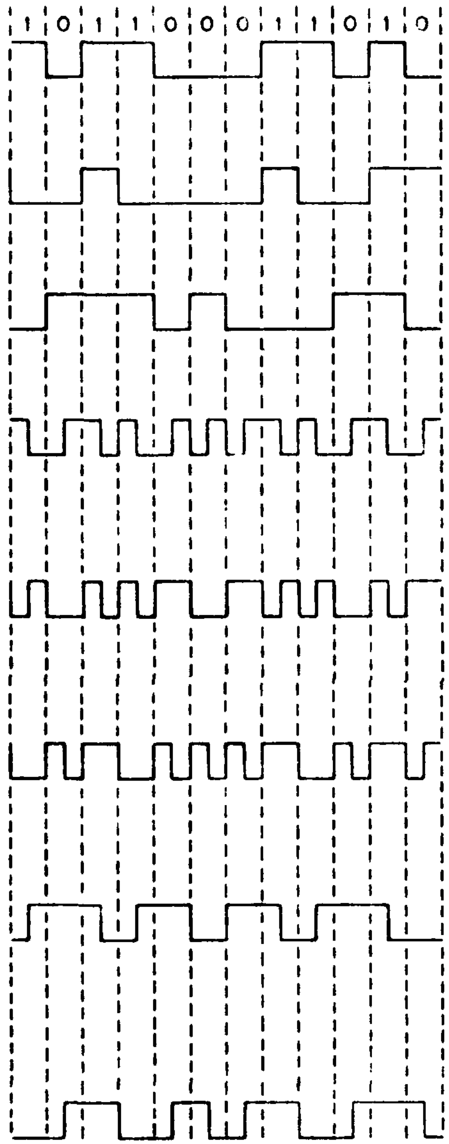


FIGURE 1A PCM CODE DEFINITION

TABLE 6

RECEIVER INTERMEDIATE FREQUENCY BANDWIDTH (3 dB)

12,500 Hz*
25,000 Hz*
50,000 Hz*
100,000 Hz
300,000 Hz
500,000 Hz
750,000 Hz
1,000,000 Hz
1,500,000 Hz
3,300,000 Hz

**System instabilities may limit the use of these bandwidths.*

4-4. Multiple and Submultiple Sampling

Data sampling at rates which are multiples or submultiples of the minor frame rate is permissible. When submultiple sampling is employed, the restrictions on minor frame length (para 4-2b.) and bit jitter (para 4-2c.) are applicable to the submultiple frame.

NOTE

A submultiple frame is defined as that period which includes one cycle of a commutator whose rate is a submultiple of the minor frame rate.

a. Submultiple Frame Synchronization Methods. Recommended methods for identifying submultiple channels are as follows:

(1) The beginning of a submultiple frame may be identified by a unique digital word within the submultiple frame and occupying the same word intervals as the submultiple frame. Each submultiple sequence will have a fixed and known relationship to the submultiple frame identification word.

(2) The beginning of a submultiple frame may be identified by a unique digital word replacing the frame synchronization word indicating start of the submultiple sequence.

(3) Each word within the submultiple sequence may contain identification bits to indicate the position of that word.

b. Maximum Submultiple Frame Length. The interval of any submultiple frame, including the time devoted to synchronizing or channel identification information, shall not exceed 256 times the interval of the minor frame in which it occupies a recurring position.

4-5. Radio Frequency and Subcarrier Modulation

a. Frequency Modulation (FM). The frequency deviation of an FM RF carrier or a subcarrier shall be symmetrical about the carrier or subcarrier frequency. The deviation shall be the same for all occurrences of the same level.

b. Phase Modulation (PM). The phase deviation of a PM carrier shall be symmetrical about the unmodulated carrier. The deviation shall be the same for all occurrences of the same level.

c. PCM/FM/FM. The subcarrier channel shall be chosen such that the maximum frequency response for the channel, as shown in Tables 2 and 3, is greater than the reciprocal of twice the shortest period between transitions in the PCM waveform.

4-6. Premodulation Filtering

Premodulation Filtering is recommended to confine the radiated RF spectrum as required in Chapter 2, para. 2-1 d. and para. 2-6 e.

CHAPTER 6

PULSE DURATION MODULATION (PDM) STANDARD

NOTE

This Standard has been deleted due to lack of use. Ranges which have an established capability are encouraged to maintain it as long as current needs exist; however, application of other standards is recommended for new programs. It is recommended that the ranges not buy new equipment related to this standard.

(5) Paragraph 7-3 b.(5) shall apply for head-stack tilt.

(6) Paragraph 7-3 b.(6) shall apply for gap scatter.

(7) The location of any head in a stack shall be within ±0.001 inch (±0.03 mm), nonaccumulative, of the nominal position required to match the track location, as set forth in b.(1),(2), (3),(4),(5), and (6) above.

c. Head Polarity. Paragraph 7-3 c. shall apply.

d. Tape Guiding. Tape guides shall provide accurate guidance of the tape across the heads without damaging the tape.

e. Tape Speeds. Paragraph 7-2 a. shall apply.

f. Bit-Packing Density. The playback device shall be capable of playing back data recorded at bit-packing densities of 1000 bits per linear inch (39.37 bits/mm) per track maximum. The nominal maximum bit-packing density at the test ranges shall be 1000 bits per linear inch (39.37 bits/mm) per track.

g. Total Bit Spacing Error. This shall not exceed 650 microinches (16.51 μm), peak-to-peak with respect to the clocks, from record to reproduce and from machine to machine.

h. Type of Recording. Nonreturn-to-zero (NRZ) mark recording shall be employed wherein a change in magnetization of the tape from maximum level of one polarity to maximum level of the opposite polarity is used to indicate the digit one, and no change in magnetization during a bit interval indicates a zero. Recorder/reproducer electronics shall be designed to meet the requirements of paragraphs j and k below.

i. Timing. Track 16 shall be reserved for range timing.

j. Recorder Input Characteristics.

(1) Input impedance shall be 20 kilohms resistive minimum, shunted by 250 picofarads maximum.

(2) Input voltage shall be 2-to-20 volts plus, minus, or symmetrical about ground, and polarity-selectable.

(3) Input format shall be parallel input, NRZ level.

k. Output Characterisitics.

(1) Reproduce output format shall be parallel output, NRZ level. Reproducer output shall compensate for all recorder/reproducer induced time-displacement errors to within 5.0 per cent of the word interval, or 1.6 microseconds, whichever is greater.

(2) Output impedance shall be 100 ohms maximum.

(3) Output voltage shall be 10 volts peak-to-peak minimum across 1.000 ohms resistance shunted by no more than 250 picofarads capacitance, one polarity for one, opposite polarity for zero, selectable polarity.

NOTE

Paragraphs 7-8., PDM Recording; 7-9., Record Amplifier; and 7-10., Reproduce Amplifier have been deleted due to lack of use. Ranges which have an established capability are encouraged to maintain it as long as current needs exist; however, application of other standards is recommended for new programs. It is recommended that the ranges not buy new equipment related to these paragraphs.

APPENDIX A

FMG FREQUENCY MANAGEMENT PLAN FOR UHF TELEMETRY BANDS

References:

a. Military Communications-Electronics Board Memoranda: MCEB-M 92-65, 19 February 1965; 105-69, 24 Feb 69; and, 323-72 1 Aug 72.

b. IRIG (RCC) Document, Telemetry Standards, Doc. 106-73.

c. Sandia Laboratories Technical Memorandum, SC-TM-68-9, "Frequency Channel Selection Subject to Constraints," February 1968.

d. Air Force Eastern Test Range/PAA Tech Staff Memo No. 71, ETV-TM-67-16, "Multiple-Link Reception Through Wideband Nonlinear Components," 31 March 1967.

1. **Purpose** - To provide guidelines for the most effective use of allocated UHF telemetry bands, 1435-1535 MHz and 2200-2300 MHz.

2. **Scope** - This plan is intended to be utilized as a guide by all managers and users of telemetry frequencies in the above bands, at National, Service, or other DOD test ranges/facilities.

3. **General** - Essential air-ground telemetering in connection with guided missile, upper air research, space, and aircraft flight testing in the past has been accommodated on a primary basis on 44 channels (500 KHz bandwidth) in the 225-260 MHz portion of the military communications band, 225-400 MHz. The Military Communications-Electronics Board (MCEB) directed DOD agencies remove all telemetering operations from this band by 1 January 1970. The frequency bands 1435-1535 MHz and 2200-2300 MHz have been allocated to satisfy displaced and/or future telemetering needs (Ref a). This plan has been devised for application where congestion of the allocated telemetry spectrum is expected to be a problem, i.e., at the National and Service Ranges and adjacent areas.

This plan is based primarily on information obtained as a result of empirical and theoretical analysis, judgements formulated on past experience, and on expectations of future requirements and equipment characteristics.

4. **UHF Telemetry Radio Frequency Assignments**

a. It has been determined that air/space-ground telemetering must be restricted to the 1435-1535 MHz and 2200-2300 MHz bands, effective 1 January 1970, in order to permit unrestricted use of the 225-400 MHz military communications band.

b. The band 1435-1535 MHz is nationally allocated for Government/non-Government

telemetry use for flight testing of manned and unmanned aircraft, missiles, and space vehicles of major components thereof on a shared basis and the 2200-2300 MHz band is allocated for Government fixed and mobile communications and telemetry on a co-equal basis.

c. Narrowband telemetry channel spacing will be increments of 1 MHz beginning with frequencies 1435.5 and 2200.5 MHz, respectively. These numbers will be used as the base from which all frequency assignments are to be made. Wideband channels are permitted and will be centered on the center frequency of narrowband channels. Accordingly, all telemetry equipment, whether for narrow, medium, or wideband channel application, must be capable of operating on any one MHz increment in the 1435-1535 MHz or 2200-2300 MHz band, without infringing upon adjacent bands.

5. Channel Bandwidth Definitions and Spacing Allocations

To satisfy various channel bandwidth requirements, the following definitions and spacing allocations will prevail.

a. Narrowband Channel. A channel with a necessary bandwidth of 1 MHz or less.

b. Mediumband Channel. A channel with a necessary bandwidth of more than 1 MHz but not greater than 3 MHz.

c. Wideband Channel. A channel having a necessary bandwidth greater than 3 MHz but not greater than 10 MHz, the assignment of which is to be determined by the service involved and based on justifiable program requirements.

NOTE 1

Channel bandwidth criteria stated in 5a, b, and c above are equivalent to occupied bandwidths not exceeding 1.2, 3.2, and 10.2 MHz respectively, when being modulated, as measured in accordance with the guidelines outlined in RCC Document, "Telemetry Standards," at 60 db down from the unmodulated carrier power.

NOTE 2

Necessary bandwidth is defined as the minimum value of the occupied bandwidth sufficient to insure the transmission of information at the rate and with the quality required for the system employed, under specified conditions and for a given class of emission.

There are duplicate spacings of 2 MHz each and there will be intermodulation between frequencies 2200.5, 2202.5, 2212.5, and 2214.5 MHz.

Spacings 2 + 4 = 6, and there will be interference between 2200.5, 2206.5, and 2212.5 MHz.

NOTE

The above group of five frequencies has intermodulation problems and would be a poor choice of frequencies.

d. To minimize interference, a maximum of ten narrowband channels (1 MHz bandwidth or less) may be used simultaneously on the same vehicle/source, within either of the two UHF telemetry bands, if their spacing is identical to the example in c(2) above.

e. To preclude interference and overcrowding of the spectrum allocated for telemetry, to the maximum extent possible, use should be made of both UHF bands, 1435-1540 MHz and 2200-2300 MHz.

7. STANDARDS FOR THE LEVEL OF UNDESIRED EMISSIONS OUTSIDE THE AUTHORIZED BANDWIDTH FOR TELEMETERING STATIONS, EXCLUDING THOSE FOR SPACE RADIOCOMMUNICATION, IN THE BANDS 1435-1535 AND 2200-2290 MHz.

7-1. General

These standards are applicable to telemetering stations, excluding those for radiocommunication, authorized for operation in the bands 1435-1535 and 2200-2290 MHz. Assignments to such stations include an assigned frequency and an authorized bandwidth centered on that frequency. The authorized bandwidth is identical to the emission bandwidth, which is indicated by the numerical prefix to the emission designators in the list of Frequency Assignments to Government Radio Stations, and to the *necessary bandwidth. These standards are applicable independently of and are not related to any present or future channelization of these bands.

**As defined by the ITU Radio Regulations and Section 6.1.1 of this Manual: For a given class of emission, the minimum value of the occupied bandwidth sufficient to ensure the transmission of information at the rate and with the quality required for the system employed, under specified conditions. Emissions useful for the good functioning of the receiving equipment as, for example, the emission corresponding to the carrier of reduced carrier systems, shall be included in the necessary bandwidth.*

7-2. Definitions

P_T = Transmitter power in watts (unmodulated carrier)

BW = Bandwidth

Authorized BW = Emission BW = Necessary BW, in MHz

F_o = Center of BW

A and A' = BW to which all emissions must, as a minimum, be suppressed 60 dB or to -25 dBm, whichever is greater.

B and B' = BW to which all emissions must, as a minimum, be suppressed in dB, $55 + 10 \log_{10} P_T$.

7-3. Standard for Authorized Bandwidth Equal to or Less Than 1 MHz

A. On each side of F_o:

Let $\frac{A}{2} = \frac{\text{Authorized BW}}{2} + \frac{\text{Authorized BW}}{2}$

Then A = 2 x Authorized BW.

Power Level Limit: In any 3 kHz bandwidth outside bandwidth A, the minimum required attenuation for all emissions is 60 dB below P_T, except that it shall not be necessary in any case to attenuate below a level of -25 dBm.

B. On each side of F_o:

Let $\frac{B}{2} = \frac{A}{2} = 0.5$ MHz.

Then B = (2 x Authorized BW) = 1.0 MHz.

Power Level Limit: In any 3 kHz bandwidth outside bandwidth B, the minimum attenuation for all emissions must be in accordance with the following formula:

X = -60 dB or to -25 dBm, whichever is greater.
Y (in dB) = $-(55 + 10 \log_{10} P_T)$.

NOTE

This limits the maximum power level outside B to -25 dBm.

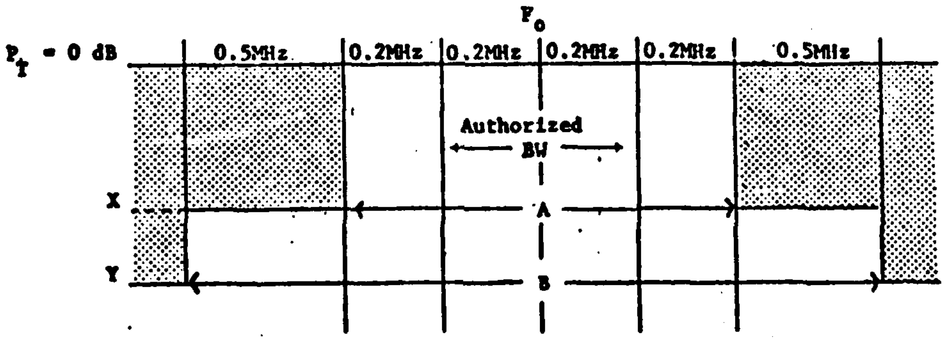
EXAMPLE 1:

Assume an Authorized BW of 0.4 MHz centered on F_0:

A = 2 x Authorized BW
  = 2 x 0.4
  = 0.8 MHz

B = (2 x Authorized BW + 1.0 MHz)
  = (2 x 0.4) + 1.0
  = 1.8 MHz

The illustration below shows the power level limit:



7-4. Standard for Authorized Bandwidth Greater Than 1 MHz

A. On each side of F_0:

Let $\frac{A}{2} = \frac{\text{Authorized BW}}{2} + 0.5$ MHz.

Then A' = Authorized BW + 1.0 MHz.

Power Level Limit: In any 3 kHz bandwidth outside bandwidth A', the minimum required attenuation for all emissions is 60 dB below P_T, except that it shall not be necessary in any case to attenuate below a level of -25 dBm.

B. On each side of F_0:

Let $\frac{B'}{2} = \frac{A'}{2} + 0.5$ MHz

Then B' = (Authorized BW) + 2.0 MHz.

Power Level Limit: In any 3 kHz bandwidth outside bandwidth B', the minimum attenuation for all emissions must be in accordance with the following formula:

X = -60 dB or to -25 dBm, whichever is greater.
Y (in dB) = $-(55 + 10 \log_{10} P_T)$.

NOTE

This limits the maximum power level outside B' to -25 dBm.

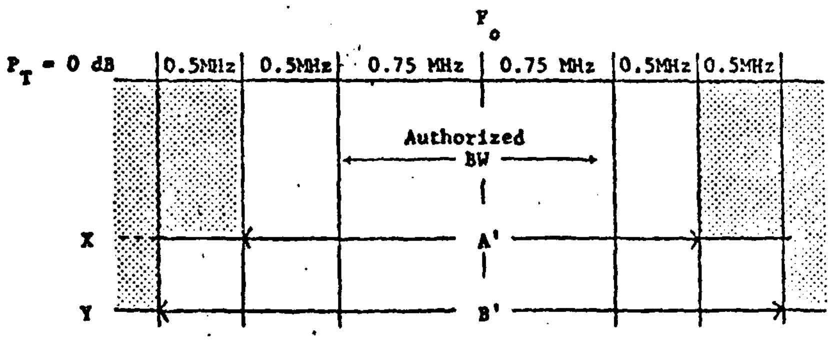
EXAMPLE 2:

Assume an Authorized BW of 1.5 MHz centered on F_o:

A' = Authorized BW + 1.0 MHz
= 1.5 + 1.0
= 2.5 MHz

B' = Authorized BW + 2.0 MHz
= 1.5 + 2.0
= 3.5 MHz

The illustration below shows the power level limit:



NOTE

(Material in paragraph 7. taken from the OTP Manual of Regulations and Procedures for Radio Frequency Management - September 1974.)

APPENDIX B

USE CRITERIA FOR FREQUENCY DIVISION MULTIPLEXING

1. General

The successful application of the Frequency Division Multiplexing Telemetry Standards depends upon recognition of performance limits and performance tradeoffs which may be required in implementation of a system. The use criteria included in this appendix are offered in this context, as a guide for orderly application of the standards which are presented in Chapter 3.

It is the responsibility of the telemetry system designer to select the range of performance that will meet his data measurement requirements and at the same time permit him to operate within the limits of the standards. A designer or user must also recognize the fact that even though the standards for FM/FM multiplexing encompass a broad range of performance limits; tradeoffs such as data accuracy for data bandwidth may be necessary. Nominal values for such parameters as frequency response and rise time are listed to indicate the majority of expected use, and should not be interpreted as inflexible operational limits. It must be remembered that system performance is influenced by other considerations such as hardware performance capabilities. In summary, the scope of the standards together with the use criteria are intended to offer flexibility of operation and yet provide realistic limits.

2. FM Subcarrier Performance

The nominal and maximum frequency response of the subcarrier channels listed in Tables 2 and 3 is 10 per cent and 50 per cent, respectively, of the maximum allowable deviation bandwidth. The nominal frequency response of the channels employs a deviation ratio of five. The deviation ratio of a channel is defined as one-half the defined deviation bandwidth divided by the cutoff frequency of the discriminator output filter.

The use of other deviation ratios for any of the subcarrier channels listed may be selected by the Range Users to conform with the specific data response requirements for the channel. As a rule, the rms signal/noise ratio of a specific channel varies as the three-halves power of the subcarrier deviation ratio employed.

The nominal and minimum channel rise times indicated in Tables 2 and 3 have been determined from the equation which states that rise time is equal to 0.35 divided by the frequency response for the nominal and maximum frequency response, respectively. The equation is normally employed to define the 10 to 90 per cent rise time for a step function of the channel input signal; however, deviations from these values may be encountered due to variations in subcarrier components in the system.

3. FM Subcarrier Performance Tradeoffs

The number of subcarrier channels which may be used simultaneously to modulate a radio-frequency carrier is limited by the radio-frequency channel bandwidth, and by the output signal/noise ratio that is acceptable for the application at hand. As channels are added, it is necessary to reduce the transmitter deviation allowed for each individual channel, to keep the overall multiplex within the radio-frequency channel assignment. This lowers the subcarrier-to-noise performance at the discriminator inputs, and the system designer's problem is to determine acceptable tradeoffs between the number of subcarrier channels and acceptable subcarrier-to-noise ratios.

Background information relating to the level of performance and the tradeoffs that may be made is included in the "Telemetry FM/FM Baseband Structure Study," Volumes I and II, DDC Documents AD-621139 and AD-621140, which were completed under a contract administered by the Telemetry Working Group of IRIG. The results of the study show that proportional bandwidth channels with center frequencies up to 165 KHz and constant-bandwidth channels with center frequencies up to 176 KHz may be used within the constraints of these standards. The test criteria included the adjustment of the system components for approximately equal signal-to-noise ratio at all of the discriminator outputs with the receiver input near radio frequency threshold. Intermodulation caused by the radio link components carrying the composite multiplex signal limits the channel's performance under large signal conditions.

With subcarrier deviation ratios of four, channel data errors on the order of 2.0 per cent rms were observed. Data channel errors on the order of 5.0 per cent rms of full-scale bandwidth were observed when subcarrier deviation ratios of two were employed. When deviation ratios of one were used, it was observed that channel data errors exceeded 5.0 per cent. Some channels showed peak-to-peak errors as high as 30 per cent. It must be emphasized, however, that the results of the tests performed in this study are based upon specific methods of measurement on one system sample and that this system sample represents a unique configuration of components. Other components with other performance characteristics will not necessarily yield the same system performance.

System performance may be improved, in terms of better data accuracy, by sacrificing system data bandwidth. That is, if the user is willing to limit the number of subcarrier channels in the multiplex, particularly the higher frequency channels, the input level to the transmitter can be increased. The signal-to-noise ratio of each subcarrier is then improved through the increased per-channel transmitter deviation. For example, the baseband structure study indicated that when the 165 KHz channel and the 93 KHz channel were not included in the proportional bandwidth multiplex, performance improvement in the remaining channels equivalent to approximately 12 db increased transmitter power can be expected.

Likewise, elimination of the five highest frequency channels in the constant-bandwidth multiplex allowed a 6 db increase in performance.

NOTE

Paragraphs 6, AM Subcarrier Background, 7., AM Airborne Systems, 8., AM Ground System, and 9., Tape Recording, have been deleted due to lack of use. Ranges which have an established capability are encouraged to maintain it as long as current needs exist; however, application of other standards is recommended for new programs. It is recommended that the ranges not buy new equipment related to these deleted paragraphs.

APPENDIX C

PCM STANDARDS

ADDITIONAL INFORMATION AND RECOMMENDATIONS

1. Bit Rate Versus Receiver Intermediate-Frequency Bandwidth (3 dB Points)

a. Receiver intermediate-frequency (IF) bandwidth should be selected from those values listed in Table 6. Only those discrete receiver intermediate-frequency bandwidths listed should be used for data channel (optional below 12,500 Hz). The selections in Table 6 have been made on the consideration that automatic tracking of radio-frequency (RF) carrier drift or shift will be used in the receiver; however, doppler shift considerations may require wide intermediate-frequency/discriminator bandwidths for the AFC system.

b. For reference purposes in a well designed system, a receiver intermediate-frequency signal-to-noise ratio (power) of approximately 15 dB will result in a bit error probability of about 1 bit in 10^6. A 1 dB change (increase or decrease) in this signal-to-noise ratio will result in an order of magnitude change (10^7 or 10^5 from 10^6, respectively) in the bit error probability.

c. It is recommended that the period between assured bit transitions be a maximum of 64-bit intervals to assure adequate bit synchronization.

2. Suggested PCM Synchronization Patterns

It is suggested that an N-bit frame-synchronization pattern be selected under the criterion that the probability of displacement of the pattern by ±1 bit be minimized at the same time, restricting the probability of pattern displacement by 2 to (N-1) bits below a prescribed maximum. A 31-bit synchronization pattern satisfying this criterion is 0101011010100101101001101010111.

3. Premodulation Filtering

Paragraph deleted.

4. Spectral Comparisons for NRZ, BIØ, and DM

Plotted in Figure C-1 are the power spectral densities of NRZ, BIØ, and DM coding. Plotted in Figure C-2 are the theoretical BER vs

SNR curves for NRZ, BIØ, and DM coding. The spectral properties of DM coding which make it attractive for magnetic tape recording include:

a. The majority of the signaling energy lies in frequencies less than one half the bit rate.

b. The spectrum is small at f=0. This spectral minimum facilitates the problem of bit synchronization.

c. A reduced power spectral density in the vicinity of f=0 is important in tape recording because tape response is poor at low frequencies.

d. As a result of subparagraphs 4.a and 4.b above, higher bit packing density can be used.

e. The NRZ-L code is insensitive to the 180° phase ambiguity that is common to DM and BIØ coding.

f. RF transmission of DM formats must consider an approximate 3.5 dB SNR penality (See report identified in the following note).

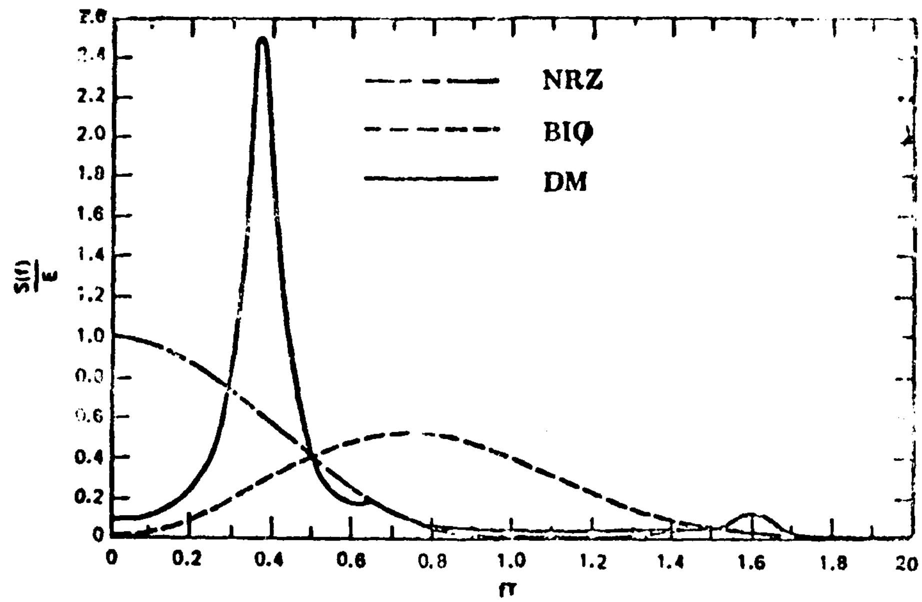


Figure C-1. Spectral Density of Random NRZ, BIØ, and DM Coding

S(f)/E is power spectral density normalized with respect to signal energy per bit.
f is frequency.
T is bit period.

NOTE

Material presented in paragraph 4 is taken from Naval Missile Center Technical Publication TP-73-18; Bit Synchronization System Performance Characterization, Modeling, and Tradeoff Study; by W. C. Lindsey, University of Southern California.

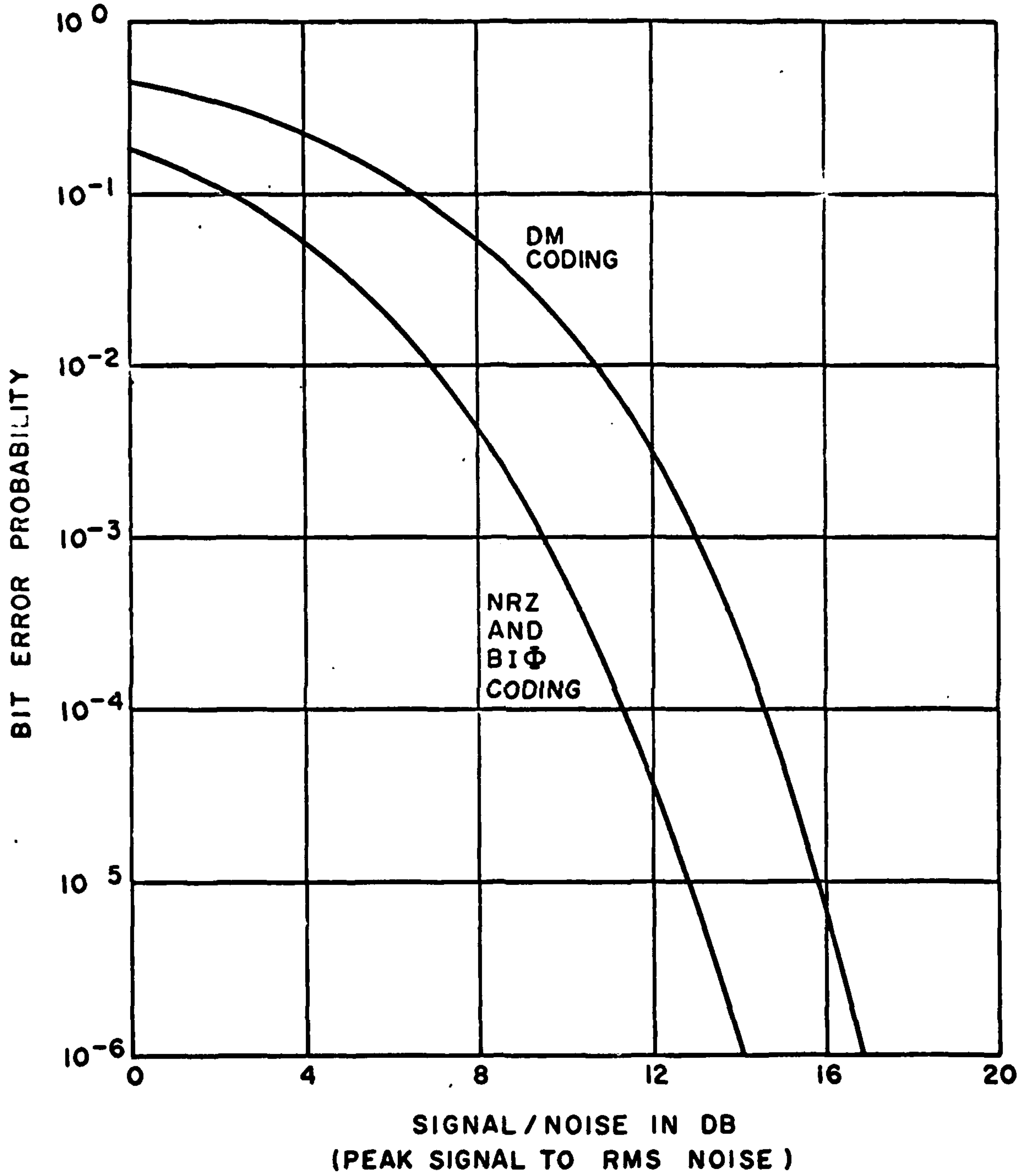


Figure C-2. Theoretical BEP Performance for Various Baseband PCM Signaling Techniques (perfect bit assumed).

APPENDIX E

PDM STANDARDS
ADDITIONAL INFORMATION AND RECOMMENDATIONS

NOTE

This Appendix has been deleted due to lack of use. Ranges which have an established capability are encouraged to maintain it as long as current needs exist; however, application of other standards is recommended for new programs. It is recommended that the ranges not buy new equipment related to this deleted Appendix.

APPENDIX G

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